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Read, Scott A. and Collins, Michael J. and Becker, Heidi and Cutting, Jeremy and Ross, Danielle and Savill, Annyk and Trevor, Beth (2009) *Changes in intraocular pressure and ocular pulse amplitude with accommodation*. British Journal of Ophthalmology, 94(3). pp. 332-335.

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## **Changes in intraocular pressure and ocular pulse amplitude with accommodation**

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**Competing Interest:** None declared

**Word count:** 2393 words

**Number of figures:** 4

**Keywords:** Intraocular pressure, ocular pulse amplitude, accommodation, myopia, refractive error

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## **Abstract**

**Aims:** To investigate the change that occurs in intraocular pressure (IOP) and ocular pulse amplitude (OPA) with accommodation in young adult myopes and emmetropes.

**Methods:** Fifteen progressing myopic and seventeen emmetropic young adult subjects had their IOP and OPA measured using the Pascal dynamic contour tonometer. Measurements were taken initially with accommodation relaxed, and then following 2 minutes of near fixation (accommodative demand 3D). Baseline measurements of axial length and corneal thickness were also collected prior to the IOP measures.

**Results:** IOP significantly decreased with accommodation in both the myopic and emmetropic subjects (mean change:  $-1.8 \pm 1.1$  mmHg,  $p < 0.001$ ). There was no significant difference ( $p > 0.05$ ) between myopes and emmetropes in terms of baseline IOP or the magnitude of change in IOP with accommodation. OPA also decreased significantly with accommodation (mean change for all subjects  $-0.5 \pm 0.5$ ,  $p < 0.001$ ). The myopic subjects (baseline OPA  $2.0 \pm 0.7$  mmHg) exhibited a significantly lower baseline OPA ( $p = 0.004$ ) than the emmetropes (baseline OPA  $3.2 \pm 1.3$  mmHg), and a significantly lower magnitude of change in OPA with accommodation.

**Conclusion:** IOP decreases significantly with accommodation, and changes similarly in progressing myopic and emmetropic subjects. However, differences found between progressing myopes and emmetropes in the mean OPA levels and the decrease in OPA associated with accommodation suggested some changes in IOP dynamics associated with myopia.

## INTRODUCTION:

The notion that mechanical force from the eye's IOP may provide a mechanism through which myopic axial elongation occurs has been proposed by a number of authors in theories of refractive error development.<sup>1,2</sup> There is a range of evidence from in-vivo and in-vitro studies of experimental animals and humans, suggesting alterations in IOP can lead to changes in the length of the eye, consistent with the notion that elevated IOP leads to a stretching of the sclera and axial elongation of the globe.<sup>3-5</sup> Our recent finding of a significant association between the diurnal variation in axial length and IOP in emmetropic human subjects also supports a potential linkage between IOP and eye length.<sup>6</sup>

The exact influence of IOP on human refractive error development is unclear. A number of cross-sectional studies of children and adults have found myopia to be significantly associated with higher IOPs,<sup>7,8</sup> however others have reported no significant association.<sup>9,10</sup> Similarly, longitudinal studies exploring the association between IOP and myopia progression have also presented conflicting findings, with some investigators reporting a significant association between IOP and myopia progression,<sup>11</sup> and others finding no such relationship.<sup>12</sup>

The accuracy of IOP measurements with applanation tonometers are known to be influenced by a range of corneal factors such as corneal thickness and biomechanical properties.<sup>13</sup> It is therefore possible that studies investigating IOP and refractive error could be confounded by an association between corneal parameters and IOP, particularly given reports of associations between myopia and corneal thickness<sup>14</sup> and corneal biomechanical properties.<sup>15</sup> These potential confounding factors could be reduced through the use of newly introduced tonometers such as the Pascal Dynamic Contour Tonometer (DCT), which is thought to be less influenced by corneal characteristics than traditional instruments.<sup>16</sup>

As near-work has been identified as a significant risk factor for myopia development and progression,<sup>17</sup> changes in IOP associated with near-work have the potential to play a role in myopia development. Previous studies utilizing applanation tonometers have noted a reduction in IOP to occur with accommodation in young subjects not selected for refractive error.<sup>18,19</sup> Relative differences in accommodative induced IOP changes between individuals could potentially be important in myopia development, however no previous study has investigated whether emmetropic and myopic individuals' exhibit differences in IOP associated with changes in accommodation.

In this current study we have examined the influence of accommodation on IOP using the Pascal DCT instrument in young progressing myopic and emmetropic subjects.

## **MATERIALS AND METHODS:**

Thirty two young adult (mean age  $23 \pm 3$  years) subjects participated in this study. Twelve of the 32 subjects were female. Fifteen of the 32 subjects were myopes (mean  $\pm$ SD best sphere refraction  $-3.74 \pm 1.88$ , range -1.25 DS to -6.00 DS), and seventeen were emmetropes (mean  $\pm$ SD best sphere refraction  $-0.03 \pm 0.22$ , range -0.50 DS to +0.50 DS). No subject exhibited astigmatism of greater than 1.00 DC. The myopic subjects were selected for evidence of progression of their refractive error of at least -0.50 DS in the 24 months prior to testing (based upon previous refraction information). No subject reported a history of any ocular pathology, surgery or significant trauma. Approval from the university human research ethics committee was obtained prior to commencement of the study and all subjects provided written informed consent and were treated in accordance with the declaration of Helsinki.

Each subject underwent an initial screening examination to determine their refractive status and ensure normal ocular health, binocular vision and amplitudes of accommodation. Additionally, all subjects underwent measurements of corneal thickness (mean of 5 corneal scans using the Pentacam HR, rotating Scheimpflug instrument, Oculus Inc, Wetzlar Germany), and axial length (mean of 5 valid axial length measures using the Zeiss IOLMaster instrument, Zeiss Meditec, Jena, Germany).

Measurements of IOP were carried out on the right eye of all subjects using the Pascal Dynamic Contour tonometer (DCT) (Ziemer Ophthalmic Systems, Port, Switzerland). The DCT is an electronic contact tonometer that works on the principle of contour matching and has been described in detail elsewhere.<sup>16</sup> The DCT provides a continuous recording of intraocular pressure (over approximately 5 seconds) and provides measures of mean IOP and ocular pulse amplitude (OPA) (defined as the difference between the diastolic and systolic IOP over the measurement time) as well as a quality score (where a score of 4 or 5 indicates an unreliable result) for each measurement. Measurements with the DCT were taken according to manufacturer instructions, following the instillation of a drop of local anesthetic (0.4 % oxybuprocaine hydrochloride). A total of 3 DCT measurements were taken for each subject at each measurement session.

Figure 1 provides an overview of the experimental protocol carried out following the initial screening measures. Baseline IOP and OPA measures were taken following seven minutes of viewing a distance target (a 6/12 Snellen letter) to ensure relaxed accommodation. Subjects maintained distance fixation for the duration of baseline IOP measurements. Subjects then fixated on a near target (an n10 size letter) for a period of two minutes (the distance of the near target was adjusted for spectacle lens effectivity in order to represent a 3 D accommodative demand for all subjects). Subjects continued to maintain near fixation whilst DCT IOP and OPA measures were taken. As the position of the instrument obscured the measured (right) eye's view of the fixation target, all fixation was carried out using the fellow (left) eye, and the accommodation response was assumed to be consensual between the two eyes. The left eye was also corrected with the subject's full distance sphero-cylindrical refraction in a trial frame. The fixation target was positioned so as to be aligned with the measured (right) eye, to ensure that the left eye converged and accommodated to view the near target, whilst the right eye accommodated but did not converge. Subjects were instructed to "maintain sharp focus on the fixation target" for the duration of the experimental protocol.

To investigate whether the IOP and OPA changes were associated with the accommodation task and not an artefact of repeated tonometry measures, a control experiment was carried out on four subjects (2 emmetropes and 2 progressing myopes). These subjects returned on a separate day and had IOP and OPA measures carried out following seven minutes of distance viewing. They then continued to view the distance target for a further two minutes and the IOP and OPA measures were repeated (i.e. accommodation remained relaxed for the duration of the control experiment).

Following data collection, the mean baseline IOP and OPA for each subject was calculated along with the mean IOP and OPA during the 3D accommodation task. Paired sample t-tests were used to investigate change in IOP and OPA with the accommodation task. Independent sample t-tests were used to investigate differences between the progressing myopes and emmetropes in terms of baseline IOP and OPA and the change in IOP and OPA induced by accommodation. Pearson's correlation analysis was used to investigate associations between IOP and OPA, and the measured ocular biometric variables (i.e. axial length, corneal thickness).

## **RESULTS:**

IOP reduced significantly as a result of the accommodation task (Figure 2). The mean  $\pm$  SD change in IOP with accommodation for all subjects was  $-1.8 \pm 1.1$  mmHg. This change in IOP was highly statistically significant ( $p < 0.0001$ ). However there was no

significant difference found between the progressing myopes and emmetropes in terms of their baseline IOP (mean baseline IOP in the myopes was  $17.6 \pm 2.0$  mmHg and the emmetropes was  $16.8 \pm 3.0$  mmHg,  $p = 0.4$ ), or the change in IOP observed with accommodation (mean change in IOP in the myopes was  $-1.8 \pm 0.8$  mmHg, and for the emmetropes was  $-1.9 \pm 1.4$  mmHg,  $p = 0.8$ ).

Correlation analysis revealed no significant association between the baseline IOP levels and central corneal thickness ( $r = 0.20$ ,  $p = 0.3$ ) or axial length ( $r = 0.22$ ,  $p = 0.2$ ). However, the change in IOP with accommodation was significantly associated with the baseline IOP level ( $r = -0.47$ ,  $p = 0.006$ ), indicating that subjects with higher levels of IOP exhibited a larger reduction in IOP as a result of the accommodation task.

Ocular pulse amplitude also decreased significantly with accommodation (mean change  $-0.5 \pm 0.5$  mmHg,  $p = <0.0001$ ) (Figure 3). The progressing myopes and emmetropes exhibited a significant difference in their baseline OPA, with the mean baseline OPA being  $2.0 \pm 0.7$  mmHg in the progressing myopes and  $3.2 \pm 1.3$  mmHg in the emmetropes ( $p = 0.004$ ). The progressing myopes also exhibited a significantly smaller magnitude of change in OPA (mean change in OPA  $-0.2 \pm 0.4$  mmHg) with accommodation compared to the emmetropes (mean change in OPA  $-0.7 \pm 0.5$  mmHg) ( $p = 0.01$ ). A significant association was also found between the baseline OPA level and axial length ( $r = -0.46$ ,  $p = 0.008$ ), with a longer axial length being associated with a lower OPA. The change in OPA with accommodation was significantly associated with the baseline OPA ( $r = -0.67$ ,  $p = <0.0001$ ), with a greater decrease in OPA occurring for higher baseline OPA.

In the four subjects who participated in the control experiment, no significant change in IOP ( $p = 0.9$ ) or OPA ( $p = 0.5$ ) was evident between the first and second measurement sessions where accommodation remained relaxed for the duration of measurements (Figure 4). The mean change in IOP and OPA following the two minutes of distance viewing was  $+0.2 \pm 1.7$  mmHg and  $+0.2 \pm 0.6$  mmHg respectively. These findings suggest the changes observed following the accommodation task are due to accommodation and not an artefact of repeated tonometry measures.

## **DISCUSSION:**

We have shown that IOP decreases significantly with accommodation in young progressing myopes and emmetropes. Our findings are consistent with a recent report from Winn-Hall and Glasser (IOVS 2009; 50:ARVO E-Abstract 2806) who also utilized the DCT instrument and found a mean IOP decrease of 1.6 mmHg and 3.6 mmHg for 2 D and 4 D accommodation tasks in young adult subjects. Previous studies with

applanation tonometry techniques have also noted similar IOP changes with accommodation.<sup>18,19</sup> In a tonographic study, Armaly and Jepson<sup>20</sup> found significant changes in aqueous humour dynamics occur as a result of accommodation, with increases in both aqueous outflow facility and aqueous inflow reported. The IOP reduction reported in our current study suggests the increase in outflow facility associated with accommodation is relatively greater than any increase occurring in aqueous inflow. The likely mechanism underlying this change is the mechanical effect of ciliary muscle contraction upon the outflow apparatus.<sup>21</sup>

The accommodative induced IOP change observed in our study was statistically significant and could be clinically significant in some cases. The maximum change in IOP we observed across all subjects was -3.7 mmHg, which could potentially influence a patient's clinical management. These findings highlight the importance of controlling accommodation (through the use of appropriate distance fixation instructions) whilst measuring IOP in both clinical and research settings.

To our knowledge this is the first study to compare accommodative induced changes in IOP between populations of young myopic and emmetropic subjects. Our progressing myopes exhibited slightly higher baseline IOPs than our emmetropic subjects, however the difference was small and not statistically significant (mean difference in baseline IOP was 0.8 mmHg), and no significant difference was found between the two groups in terms of the magnitude of accommodative induced IOP change. There was also no significant association between axial length (or spherical equivalent refraction) and the baseline IOP level. These findings tend to not support a simple mechanical role for IOP in the aetiology of myopic axial elongation. However, as our study was cross sectional in nature, there remains a possibility that IOP changes over time, or differences in diurnal IOP fluctuations may influence eye growth in myopia.

We also found that accommodation leads to a significant decrease in OPA. Winn-Hall and Glasser (IOVS 2009; 50:ARVO E-Abstract 2806) also found decreases in OPA with accommodation in populations of young and older adult subjects. OPA represents the dynamic changes occurring in IOP due to changes in ocular blood flow across the cardiac cycle. OPA is therefore thought to provide information regarding intraocular blood flow, but is also likely to be affected by the overall rigidity of the globe.<sup>22,23</sup> Whilst the exact mechanism underlying this accommodative induced reduction in OPA is not clear, we found a significant correlation between the change in OPA and the change in IOP. The reduction in OPA with decreased IOP may therefore reflect changes occurring in ocular rigidity with IOP (i.e. a reflection of the visco-elastic properties of the globe). Ocular rigidity has been previously found to be lower at lower IOP levels.<sup>22,24</sup> A reduction in ocular rigidity with a lowering of IOP would be expected to lead to a concomitant reduction in OPA as we have found in our current study. Alterations in



ocular blood flow may also underlie OPA changes, and future studies of ocular blood flow may improve our understanding of the aetiology of accommodative induced changes in OPA.

In contrast to our IOP findings, significant differences were apparent in OPA between the progressing myopes and emmetropes in terms of baseline OPA and the change in OPA with accommodation. We also found a significant association between OPA and axial length, with longer axial lengths being associated with a lower OPA. Previous investigators have also found significantly lower OPAs in myopes.<sup>23,25</sup> James et al<sup>25</sup> suggested that the larger volume of the myopic eye may be contributing to the reduced OPA observed in myopes, as the inflow of blood into the eye with the pulse will lead to less relative change in ocular volume in larger eyes and hence a lower OPA. The significant association between axial length and OPA is consistent with this notion. However, the difference in OPA between the two populations of subjects could also reflect differences in ocular rigidity, or ocular blood flow between myopes and emmetropes. Previously documented changes in scleral structural and biomechanical properties associated with myopia<sup>26</sup> could therefore potentially underlie the difference in OPA we have found in our current study.

In conclusion, IOP and OPA both reduced significantly with accommodation. Progressing myopic and emmetropic subjects exhibited no significant difference in their baseline IOPs or in the magnitude of change in IOP associated with accommodation. However, progressing myopes exhibited a significantly lower baseline OPA and a significantly smaller magnitude of change in OPA associated with accommodation, suggesting some differences in IOP dynamics associated with the larger myopic eye.

#### **ACKNOWLEDGEMENTS:**

Aspects of data from this study were presented at the 2009 meeting of the Association for Research in Vision and Ophthalmology.

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## FIGURE LEGENDS:

**Figure 1:** Overview of experimental setup to investigate the influence of accommodation on IOP and OPA. All subjects maintained distance fixation for 7 minutes prior to the baseline 'relaxed accommodation' measures of IOP and OPA. Fixation was then directed to the near target for 2-minutes, and measures of IOP and OPA repeated whilst the subjects fixated on the near target. The left eye was corrected with the full distance sphero-cylindrical refraction with a trial frame and trial lenses.

**Figure 2:** The influence of accommodation on IOP. The change in IOP with the 3 D accommodation task was highly statistically significant ( $p < 0.0001$ ), but there was no significant difference between the populations of progressing myopes and emmetropes in terms of baseline IOP or the change in IOP with accommodation ( $p > 0.05$ ). Error bars represent standard error of the mean.

**Figure 3:** The influence of accommodation on OPA. The change in OPA with 3 D accommodation was highly statistically significant ( $p < 0.0001$ ). The progressing myopic subjects exhibited a significantly lower baseline OPA ( $p = 0.004$ ) and a significantly lower magnitude change in OPA with accommodation ( $p = 0.01$ ). Error bars represent the standard error of the mean.

**Figure 4:** Mean IOP (left) and OPA (right) observed with relaxed accommodation in the four subjects participating in the control experiment. Error bars represent standard error of the mean.